NOTES

ON

TUBE WELLS

IN THEORY AND IN PRACTICE

FOR

Irrigation purposes and Public Water Supplies.

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PREFACE.

It is not so many years since Engineers when requiring to determine the yield of an ordinary well, pumped, or otherwise lowered the water level in the well to any extent, usually limited to the power of the pumping plant available, the yield was then calculated from the rate of recuperation, or the discharge of the pump.

In most cases the discharges thus obtained are many times higher than the wells would yield under a constant demand, and if taxed to the thus estimated yield, would, in a very short time silt, or choke up.

The Hon'ble Mr. J. T. Farrant, late Chief Engineer, Punjab Public Works Department, was, I believe, the first Engineer to establish, and reduce to formulae, the theory of critical velocities for ordinary wells. By these formulae, the safe yield of any proposed well can be accurately determined, the nature of the subsoil being known.

It occurred to me that tube wells for large discharges of water, free from sand, could be made, if designed to work within this recognized critical velocity of water passing through fine sand, and with this object in view, experiments extending over several years have been carried out.

As a result of these experiments, convoluted tube wells have been made on this principle, and have been proved to fulfil all the conditions for which they are designed.

The adoption of convoluted tube wells for public water supplies has been recommended by the Sanitary Engineer to Government, Punjab, who reports that "the benefits to the Province at large which will accure from the proved success of the experiments, will be great".

The following notes, although far from complete, will I hope, be useful to those interested in tube wells.

T. B.

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Abyssinian Tube wells.

Until recently, tube wells were employed to draw only comparatively small quantities of water from the subsoil, the type familar to most people is the Abyssinian pattern. This consists of a short length of four or five feet of one and a quarter or one and a half inches diameter wrought iron tube, perforated with small holes and having wrapped round it a layer of fine copper or brass gauze to act as a straining material ; over this, as a protection to the gauze a layer of perforated thin sheet metal is secured. One end of this straining tube is provided with a steel driving point and the other end is connected to a length of plain wrought iron tube. The tube well thus formed is driven vertically into the ground and a hand pump is attached to the upper end of the plain tube.

When water is pumped from the Abyssinian tube well there is at first a considerable quantity of fine sand delivered with the water and if pumping is continued the flow of water will gradually diminish and probably cease altogether. This stoppage of flow is caused by the comparatively high velocity of water through the straining material, bringing with it the finer particles of sand, some of which pack up on the outside of the straining material forming an almost impermeable "conglomerate," the remainder pass through the straining material and are carried up to the pump, but, as packing round the straining material increases the velocity is insufficient to carry the particles to the pump and they settle at the bottom of the tube well, gradually closing up the inside of the strainer.

In order to obtain a constant supply of water from these tube wells they require to be "educated up" to the demand to be made on them. On the first sign of diminution of supply, the pump plunger should be operated to allow air to pass below it and suddenly release the head caused by the vacuum due to pumping, thus a reverse flow through the strainer is caused which displaces the finer particles of sand and on again pumping, these are carried through the strainer up to the pump. By repeating this operation several times the sand surrounding the strainer is washed of its

finer particles, and a pear shaped cavity of coarse sand is formed round the strainer. When this stage is reached the tube well is giving its best results and any more convenient form of pump may be substituted for the "sinking" pump, it must, however, be noted that the power of the pump should remain the same as that used for sinking. If a more powerful pump is employed then the coarse sand cavity is enlarged owing to the increased velocity through the strainer carrying more of the fine sand into the tube, and, the clearing operations have to be again performed until the subsoil surrounding the strainer adapts itself to the new conditions imposed by the higher power of pump.

Fig. I shows the Abyssinian tube well and the approximate shape of cavity *formed round the short strainer, this so called* cavity is only a cavity in the sense that it does not contain the finer grains of sand.

The dotted line B, Fig. I represents the point of change from the ordinary stratum to the washed sand free from fine grains surrounding the strainer. The cubic capacity of this cavity can be calculated as its superficial area is such that the water pumped, passes through this surface at a velocity of from half an inch per minute to three quarters of an inch per minute ; these velocities being the critical velocities for sandy and clayey soils, therefore, if the stratum is known the size of cavity can be fairly accurately computed.

Experiments with Abyssinian tube wells show, that when pumping is carried on at a rate which represents a velocity through the strainer of half an inch to one inch per second, the well will yield a constant supply of water free from sand, with velocities above one inch per second, traces of sand are frequently found in the water, and in strata where sand is fine, velocities of two and three inches per second will absolutely choke up the tube well.

This type of tube well is of course limited to comparatively small supplies, five gallons to fourteen gallons per minute or say up to 800 gallons per hour, larger tubes cannot be driven into the ground as they are liable to split and the fact that the gauze straining material is placed in contact with the perforated tube reduces the water way area by sventy five per cent. that proportion being taken up by the wires forming the gauze. Owing to the fineness of the wires necessary in a small mesh gauze, the straining material is extremely perishable and requires renewal on an average, every two years.

Cook's tube well.

The American patent tube well, known as "Cook's Tube." has been in use for a number of years, and the sizes commonly in use are for discharges of seven to eight thousand gallons per hour.

This tube well consists of a plain brass tube having throughout its entire length, and at intervals of approximately one fifth inch, circumferential slots about one inch in length, for general purposes a width of slot of one hundreth part of an inch is suitable; the metal at the edges of the slots is bevelled off on the inside of the tube, in order to allow grains of sand which are carried up to the slot during the clearing operations, passing easily through into the tube, instead of packing against the outside and partially closing the slot. Fig. II shows the arrangement and shape of slots employed. Supposing a tube well is required for a supply of 5,000 gallons per hour, and the subsoil water level is not to be reduced at the tube more than five feet, then by Weisbach's formula a three inch pipe delivering 5,000 gallons per hour will absorb 2·9 feet in friction in a length of 100 feet, the velocity in the tube being 4·5 feet per second. In a three inch pipe one inch long there will be 45 slots each $\frac{3}{4}$ inch long and say one hundredth of an inch wide; then for a velocity of 1 inch per second through the slots, the total area of slots would require to be; area in square feet $= \frac{\text{discharge in cubic feet per second}}{\text{mean velocity in feet per second}} = \frac{0{\cdot}22}{0{\cdot}08} = 2{\cdot}75$, and 2·75 square feet represents a tube length of 98 feet.

A greater velocity than one inch per second would result in packing of the sand particles against the slots at the upper end of the tube where the suction effect in greatest and the slots would be gradually closed up, resulting in a higher velocity through the remaining slots, and consequently hastening the closing of these also; as the closing of the slots is in progress the finer particles are passing more rapidly through the slots, and the proportion of fine sand to water becomes such, that the interior of the tube also is closed, and requires to be washed out before pumping can be continued. The experiments made with this type confirm the assumption that, with tube wells the critical velocity is between half an inch and one inch per second, or say sixty times the critical velocity in open wells. The Cook's tube is perfectly suited for moderate supplies but being somewhat difficult to slot, is expensive.

Tube well at Lahore.*

In 1909 a tube well was sunk at Lahore, this consisted of 40 feet of $4\frac{1}{2}$ inch diameter wrought iron pipe perforated with holes, the total area of the holes amounted to 14·1 square feet in the 40 feet length of tube. This tube, the metal of which was $\frac{3}{16}$ths inch thick, was wound with a spiral of brass wire, $\frac{1}{8}$ inch diameter, and over this wire fine brass gauze 40 meshes per lineal inch was wrapped. In gauze of this mesh the waterway area is 55 square inches per square foot, and as the diameter covered by gauze was $5\frac{1}{8}$ inches, therefore, in the length of 40 feet there were 68·76 square feet of gauze having 26·26 square feet of water way area, or almost twice the area of holes in the tube.

The change in velocity, of water passing through the gauze, and thence through the holes, caused by this great difference in water way area, produces eddies in the tube, and diminishes to a very large extent the discharge. This tube well under a head of 7 feet discharged 3,000 gallons per hour or 8 cubic feet per minute, the actual head absorbed in pipe friction being 0·3 foot and the approximate head absorbed between strainer and perforations being 4 feet.

The velocity through the strainer being greater than the critical velocity in unprotected sand, resulted in a certain amount of sand being brought into the tube which accumulated under the low heads and was disturbed, and carried out of the tube under heads from 10 to 14 feet, when the discharging velocity rose to 2·6 feet per second, that velocity being sufficient to hold most qualities of sand in suspension.

The experiments were of short duration and none appear to have been carried out for more than twenty to thirty minutes at one time, and the constant starting and stopping of the pump at such short intervals is bound to have produced an oscillation in the water column in the tube, the effect of which is exactly similar to that created in the Abyssinian tube well in order to clear the fine sand from the strainer.

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* *Vide* Punjab Public Works Department paper No. 62, Tube Well Experiments, also paper No. 63 Notes on the Yield of Wells by the Hon'ble Mr. J. T. Farrant, Chief Engineer.

With a gauze of 40 spaces to the lineal inch, the safe head would be approximately 7 feet, and if a pump with capacity of 3,000 to 3,500 gallons per hour had been employed constantly for eight or ten hours per day, there is no doubt that all sand would have been removed from the tube in a day or two, and the after discharge would have been steady and free from sand.

The experiments are of interest in so far that they show the loss in discharge caused by the large difference in water way area of the straining material and perforations.

Critical velocities for ordinary wells.*

Experiments on the yield of ordinary wells have been carried out in India since 1879, and during recent years a vast amount of valuable data has been collected. The result of these experiments as far as critical velocity is concerned, is briefly, that water can be taken from any well sunk in sand, at a rate which does not exceed an inflow rate of two and a half feet per hour, and for wells sunk in clayey soil, at a rate of inflow of three and a half feet per hour. These velocities are equal to 0·5 and approximately 0·7 inch per minute, respectively.

If water is pumped from wells at a rate which will cause a greater inflow velocity than this, then the capillary tubes in the sand are broken up and "blowing" commences on the surface of the sand forming the well floor; the more the velocity is increased the deeper is the disturbance in the sand, the disturbance spreads laterally as well as vertically, breaking up the sand under the well curb, and endangering the stability of the well.

The safe limit to which water can be lowered in any well is therefore 5 feet to 7 feet below subsoil water level, according to the strata, and this safe limit is not affected by the depth of water in the well.

* See Public Works Department paper No. 178, by Mr. Dawson, Manual of Irrigation wells by Mr. Maloney.

Punjab Public Works Department paper No. 63 Notes on the yield of wells, by the Hon'ble Mr. J. T. Farrant.

Critical velocities for tube wells.

In order to find the Critical velocities in sand, when tube wells are employed, the writer fitted a short length of straining tube horizontally in a tank, one end of the tube discharging through the side wall of the tank.

The tank was then filled with a mixture of fifty per cent. fine sand and fifty per cent. coarse sand, the fine sand being that which would pass through a sieve of 1,600 meshes per square inch, and the coarse sand that which was retained on the same sieve.

The tank was then gently filled with water, spreading plates being used to prevent disturbance of the sand, observations were made of the effect on the sand of various straining velocities ; the water level being kept constant at the head under observation. These experiments show that with a velocity of six inches per second through the strainer, the finest sand passes through the strainer and is discharged at the pipe mouth in considerable quantities, the coarser sand packing up on the outside of the strainer, and after a short time blocking up to such an extent, that the flow is considerably reduced, and the velocity from the tube is insufficient to carry off all the fine sand which has passed into it. Similar results, but, less marked, were observed on all heads creating velocities down to two and a half inches per second, and on velocities of less than two and a half inches per second, the fine particles of sand close to the strainer were carried through the strainer, and discharged from the tube during the first few minutes of flow, and packing on the outside of the strainer was observed to a slight extent. At velocities of three quarters and half inch per second there was no apparent change in the sand structure surrounding the tube, and only a slight trace of sand was discharged for a few minutes on starting the experiment, after which the water was free from sand.

The conclusions to be drawn from these experiments appear to be that a safe mean velocity for tube wells is half an inch per second, and also that a very fine straining material is unnecessary, provided this velocity is not exceeded, and the diameter of the tube is such, that the delivering velocity will be at least three and a

half feet per second, this velocity is necessary if the water is to keep in suspension the fine sand passed by the strainer. A most important point which should be observed is, that in clearing the sand surrounding a newly sunk tube, particular care is taken in selecting the clearing tubes, and the depths to which these are lowered. If a tube one half the diameter of the strainer is employed, and lowered more than one half the depth of the strainer at the commencement of clearing then pumping should be very cautiously carried on or the increase in velocity, and consequently friction, is so great, that the water withdrawn will be insufficient to keep the sand in suspension, and the tube well as a whole will become absolutely choked with sand.

When a tube well is made in such a way, that the discharging current is in direct contact with the straining material, then the discharging current acts as a blind on the surface of the strainer, and prevents the free passage of water through the strainer. This blinding action takes place whether pumping is done from the top of the strainer, or the bottom; in the latter case, friction is at least doubled, and the blinding action correspondingly intensified.

Investigations made with a small tube composed of straining material only, show that with an inlet velocity through the straining material of half an inch per second, and a delivering velocity from the tube of approximately three feet per second, the particles of water pass through the strainer, and creep along its inside, for a distance which may be as much as quarter of an inch, before they are caught up in the current created by the suction tension. This feature is well known, and the Cook's tube and Smith's well casing are designed with their slots at such a distance apart, that the particles of water passing through one slot have freed themselves from the tube surface, before reaching the next slot. The remedy would appear to be the introduction of an inner perforated tube, having the perforations large enough to prevent blinding and the area of metal sufficient to retain the high velocity current in the inner tube, the water passing through the straining material would then follow the line of least resistance and stream direct to the inner tube, there being caught up in the high velocity current.

A tube well of this form would be considerably shorter for a fixed percolation velocity than a tube well composed of straining material only.

The Theoretical Tube well.

The observations on the foregoing types of tube wells, and from the experiments on straining tubes and screens, result in the following conclusions.

That the straining material should not be in direct contact with the perforated tube as the area of perforations is thereby reduced by the amount of wire or other material composing the portions of straining material which are in contact with the perforations.

The straining material should be a certain distance away from the perforated tube, and this distance should be such, that the waterway area, in the straining material, is equal to the waterway area in the perforated tube, thus causing no change in velocity between the straining material and the tube.

The critical velocity for tube wells in very fine sand may be taken at half an inch per second, or sixty times greater than for ordinary wells.

The discharging velocity should be not less than three feet per second nor more than five feet per second.*

The superficial area of metal in the perforated tube should be more than twice the area of perforations, in order to prevent eddies or back flow at the perforations.

The straining material should present a maximum amount of waterway area per foot length of tube, consistent with fine openings and heavy wire or other material which will withstand moderately rough handling in transport, and lowering, and will be lasting.

* This corresponds with the practice of pump manufacturers.

Convoluted Tube well.—(*Patented*).

The writer in designing this form of tube well has endeavoured to meet the above requirements. Fig. IV shows the general design of this tube which is made of thick sheet steel, is light for transport and easily handled when sinking. The longitudinal convolutions render the tube exceedingly strong and rigid and are made of such a depth that there is no increase in velocity between the straining material and the perforations in the tube.

The proportion between the area of perforations and the area of metal is such, that eddies are reduced to a minimum, and "creeping" along the inside of the straining material is also prevented, the discharging current being concentrated, the fine streams of water percolating through the strainer pass straight through the short intervening space, into the main perforated tube.

The straining material consists of heavy copper wires lying parallel, the necessary fine space being maintained by the wires being woven at short intervals, with pairs of fine copper ribbons which prevent slipping, or other alteration of the position of the wires when the tube is handled, or in sinking. This form of straining material has about ten times the life of copper gauze, and is very considerably stronger.

Before the copper straining material is fixed, the tubes are treated to two coats of Callendar's "Kalbitum" as a rust preventative.

Convoluted Tube Wells are made in several sizes for discharges varying from one quarter, to two cusecs, or in other words, from 5,625 to 45,000 gallons per hour, these sizes have been standardized and are all made from the plain sheet on one machine, this resulting in remarkably cheap tube wells.

When used for increasing the supply of water to an ordinary well, the upper end of the "convoluted" tube should have a length of plain tube attached to it, this plain tube should be sufficiently long to project at least two feet above the floor of the well, and the top of the convoluted tube should be ten feet below the floor of the well. In deep wells the plain pipe should project inside the well

to seven feet below the normal water level. There are certain conditions of subsoil when this position of tube well has to be considerably altered, but generally, the above arrangement is satisfactory.

Convoluted Tube Wells are particularly adapted for direct pumping from the tube, and in cases where spring level is near the ground surface, the plain pipe may be used as the suction pipe of the pump. When spring level is at a considerable depth below ground surface then an alteration has to be made in the plain tube to take a suitable deep well pump.

A recuperation curve is shown for a "Convoluted" tube well designed to discharge one half cusec. or 11,250 gallons per hour, when working under a head of seven feet. The actual discharge is approximately twenty per cent. greater than the tube was designed for, and the recuperation curve plotted from the actual discharges under each foot of head practically coincides with the theoretical recuperation curve, plotted from the "time constant."*

The recuperation curve clearly shows that the discharge varies directly as the head, and this well known feature tempts some users of tube wells to increase the head and obtain a larger supply of water. The result of such increase of head is that the critical velocity is exceeded, and the tube well is sooner or later silted up and rendered useless.

* I am indebted to the Hon'ble Mr. J. T. Farrent, late Chief Engineer, Punjab Public Works Department, for his original formula for the "Time Constant" for recuperation tests.

*Irrigation from convoluted tube wells by pumping.

Until electric power is distributed over areas uncommanded by Canal Irrigation, or over areas which have become water logged, owing to excessive canal irrigation, and in which it is desired to stop or considerably reduce this system of irrigation and pump water from the subsoil, liquid fuel must be looked to as the source of power for such purposes.

Various schemes for harnessing the rivers of the Punjab have been prepared from time to time by prominent engineers, but owing to Eastern lack of enterprise those projects appear to have been indefinitely postponed.

From the data given in the projects, and from experience of hydro-electric schemes in other countries, there is not the slightest doubt that electrical energy can be supplied at consumers terminals at a rate not exceeding one anna per horse power hour.

That liquid fuel compares not unfavourably with this rate is well known, and experience has shown that oil engines from six to over thirty horse power, can be run on $\frac{3}{4}$ pint low grade kerosine oil, per break horse power, per hour.

For purposes of calculation one cusec. of water raised thirty feet for twenty four hours, will be taken as the unit, but it should be noted that if two cusecs. were taken, then the original cost of pumping plant would be considerably less than double the cost of one cusec. plant, consequently depreciation would be less, while attendance would remain the same for both plants.

The horse power required to raise one cusec. thirty feet is $\frac{62 \cdot 5 \times 30}{550} = 3 \cdot 4$ nett, and with an efficiency of 0·5 for engine and pump, the gross horse power would be 6·8.

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* I am deeply indebted to the Hon'ble Mr. J. T. Farrant late Chief Engineer, Punjab Public Works Department, for the valuable notes he so kindly supplied to me on this subject and on Irrigation by bullock power.

The consumption of oil per day is $6{\cdot}8 \times 24 \times 0{\cdot}75 = 122{\cdot}4$ pints, and low grade kerosine oil can be purchased in bulk at $9{\cdot}5$ annas per gallon. The cost per day is therefore $\frac{122{\cdot}4 \times 9{\cdot}5}{16 \times 8} =$ Rs. 9·084, adding Rs. 0·31 for lubricating oil, etc., and Rs. 0·581 for attention of a visiting driver at Rs. 18 per month for the one plant, then the total cost is Rs. 9·975 or say Rs. 10 per day of 24 hours.

With electric power at one anna per horse power hour, and motor and pump efficiency of 0·55, the gross horse power is 6·2 and and the daily cost $6{\cdot}2 \times 24 \times \frac{1}{16} =$ Rs. 9·3 *plus* 0·31 for lubrication and half the attention of visiting driver at Rs. 0·29 giving a total of Rs. 9·9 say Rs. 10 per day of 24 hours, in which 86,400 cubic feet of water is pumped.

Therefore the cost per acre foot is Rs. 5.

Allowing 75 days for the sowing period of the Rabi crop, and 5 inches in depth for the first watering, and an efficiency factor of $\frac{5}{6}$ths. which allows for $\frac{1}{6}$th loss by evaporation and absorption, then the area irrigated to a depth of 5 inches is $75 \times 2 \times \frac{12}{5} \times \frac{5}{6} =$ 300 acres.

In the remaining 105 days of the Rabi crop period, 210 acre feet of water are delivered, of which $\frac{5}{6}$ ths or 175 acre feet reach the fields, giving them an additional depth of $\frac{175}{300} \times 12 = 7$ inches, or twelve inches in all; which is the amount required.

The cost of pumping for the Rabi crop is therefore, first watering 75 days at Rs. 10 = Rs. 750 for 300 acres, or Rs. 2·5 per acre.

Subsequent waterings 105 days at Rs. 10 = Rs. 1,050 for 300 acres or Rs. 3·5 per acre.

The total cost per acre being Rs. 6.

For the Kharif crop a total depth of two feet of water is required, and the total crop period being 180 days the area which can be irrigated with an efficiency of $\frac{5}{6}$ ths. is $180 \times 2 \times \frac{5}{6} \times \frac{1}{2} =$ 150 acres. Allowing the first watering 6 inches deep, the period is

45 days, and the cost 45×10=Rs. 450 for 150 acres or Rs. 3 per acre.

In the remaining 135, days the waterings amount to a depth of 18 inches, and the cost is 135×10=Rs. 1,350 for 150 acres or Rs. 9 per acre.

The total cost per acre being Rs. 12.

The annual cost is therefore Rabi 300 acres at Rs. 6 per acre= Rs. 1,800, Kharif 150 acres at Rs. 12 per acre=Rs. 1,800, being a total of 450 acres irrigated annually for Rs. 3,600, or an average of Rs. 8 per acre per annum.

A tube well of one cusec. delivery, irrigating 450 acres annually, or say 70 per cent. of its commanded area, is sufficient for 640 acres, or one square mile.

The estimated cost of the entire pumping plant is as follows :—

	Rs.
* Convoluted tube well of 1·25 cusecs' capacity ...	930
Sinking charges	170
Direct coupled oil engine and pump, erected complete	4,000
Engine house	700
Distributing tank, etc.	200
Total	6,000

* For subsoils of low porosity a 1·25 cusecs. tube is allowed.

The annual recurring charges would be,

	Rs.
Interest on Rs. 6,000 at 4 per cent. ...	240
Depreciation of plant at 5 per cent.	300
Power, including attention as above	3,600
Collection of dues (allows one patwari for two square miles)	135
Total ...	4,275

The average rate which can be charged is therefore Rs. 9-8-0 per acre per annum.

Irrigation by Bullock power from ordinary wells.

A well twelve feet in diameter will yield 2,500 gallons per hour, and when a modern pattern bullock power chain pump is used, one pair of good bullocks will lift 2,400 gallons 30 feet, per hour per day of ten hours (say $\frac{1}{9}$th cusec). Nine tenths of the water will reach the fields, $\frac{1}{10}$th being evaporation and absorption losses. One pair of bullocks will cost Re. 1 per day.

The area irrigated daily is therefore $\frac{384 \times 10}{43,560} = 0 \cdot 88$say, $\frac{1}{12}$ acre foot.

For the Rabi crop period of 180 days at 1 foot depth of water, the area irrigated is $180 \times \frac{1}{12} = 15$ acres ; and for the Kharif crop period of 180 days at 2 feet depth of water, the area irrigated is $180 \times \frac{1}{24} = 7 \cdot 5$ acres.

The cost of the Rabi crop is therefore $\frac{180 \times 1}{15}$ = Rs. 12 per acre, and the cost for the Kharif crop is $\frac{180 \times 1}{7 \cdot 5}$ = Rs. 24 per acre.

The average cost is therefore $\frac{180 \times 2 \times 1}{22 \cdot 5}$ = Rs. 16 per acre per annum.

Allowing for depreciation and interest on the bullock pump, then the average cost per acre per annum, amounts to Rs. 17·2, or nearly double the cost of irrigation by liquid fuel, or electric power.

Public water supplies from tube wells.

There are many towns and villages in India in which the chief source of water supply is the village tank, generally a slime covered muddy depression, filled with a highly discoloured and offensive liquid, in which the buffaloes wallow, clothes are washed, the villagers bathe, and use for drinking and cooking purposes.

If an ordinary well water supply was to be introduced to a village of this nature with say 15,000 inhabitants, then land for wells would have to be acquired at some distance from the village. Allowing only ten gallons of water per head per day, from wells yielding 2,500 gallons per hour, and if pumping is carried on for 8 hours daily, then $\frac{1,500 \times 10}{2,500 \times 8} = 7\frac{1}{2}$, say 8 wells would be required.

Assuming that the wells are situated half a mile from the village in order to prevent contamination from surface percolation, and that water is pumped from the wells to an elevated central tank in the village, fitted with washing places and necessary taps, etc., to replace on sanitary lines, the requirements of the original tank.

	Rs.
The cost of this scheme would be as follows :—	
Land to be acquired for 8 wells at 130 feet by 130 feet per well, say 3 acres at Rs. 2,000 ...	6,000
Cost of 8 wells 12 feet diameter with a water depth of 60 feet, including suction connections, at Rs. 3,500 each	28,000
Cost of 1,000 feet of suction pipe and 2,500 feet of 7 inch rising main	9,500
One oil engine and pump to lift 315 gallons per minute, tanks being 30 feet above ground, and water 20 feet below ground, and friction in 3,500 feet of 7 inch pipe is 23 feet. The horse power power is therefore $\frac{315 \times 73 \times 10}{33,000} = 10 \cdot 3$, and with $0 \cdot 5$ efficiency the gross horse power is $\frac{10 \cdot 3 \times 100}{50}$ = say 20	7,500
Cost of water tank and engine house	14,000
Total cost of scheme	65,000

The annual maintenance of this scheme would be as follows :—

	Rs.
Oil consumption $\frac{20 \times 8 \times 0{\cdot}75 \times 365}{8} = 5{,}475$ gallons at 9·5 annas per gallon	 3,251
Interest on 65,000 at 4 per cent.	 2,600
Depreciation on 65,000 at 5 per cent.	 3,450
Driver and lubricating oil	 480
Total	 9,781

say Rs. 9,800 per annum.

For the same supply of water from a "Convoluted" tube well, the tube can be sunk below contamination level, at the site of the original tank.

	Rs.
Cost of 1·25 cusec. tube for low porosity subsoils	930
Sinking charges 50 feet below normal ...	350
Cost of 200 feet of pipes	600
Sand traps and masonry work	1,800
Oil engine and pump to lift 315 gallons per minute a total height of 53 feet including friction, and with 0·5 efficiency, the gross horse power is 10	4,800
Water tank and engine house as before ...	14,000
Total	22,480

The total cost of the scheme say Rs. 22,500.

The annual recurring charges on this scheme would be as follows:—

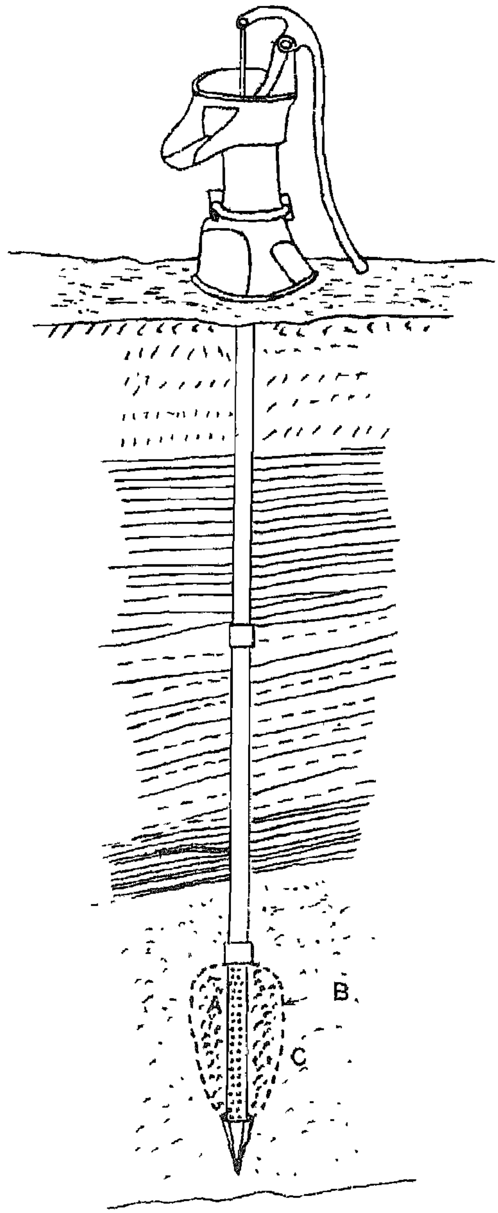
	Rs.
Oil consumption $\frac{10 \times 8 \times 0{\cdot}75 \times 365}{8}$ =2,738 gallons at 9·5 annas per gallon say	... 1,626
Interest on Rs. 22,500 at 4 per cent.	 900
Depreciation on Rs. 22,500 at 5 per cent.	 1,125
Driver and lubricating oil, etc., as before	... 480
Total	... 4,131

say Rs. 4,200 per annum.

By using tube wells the direct saving is therefore Rs. 42,500 on the initial cost of the scheme, and a further annual saving of Rs. 5,600.

The sum of Rs. 4,200 distributed among 15,000 inhabitants would mean an annual taxation of less than five annas per head, a small sum for even the most impecunious to pay, for a fairly liberal supply of wholesome water.

Fig. I.

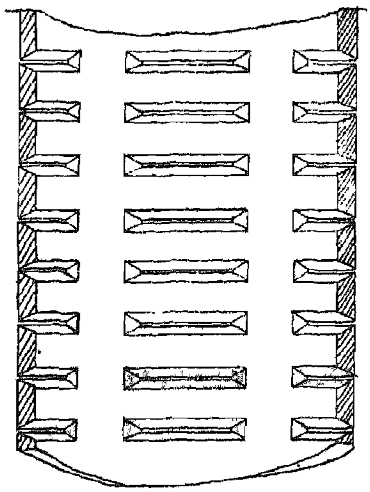


A.—Represents the so-called cavity from which the fine sand only has been pumped out

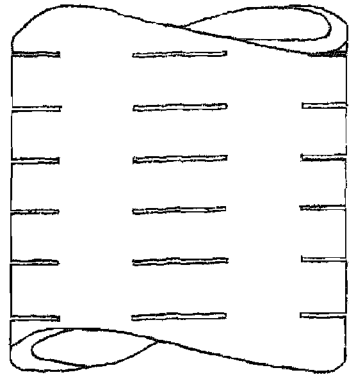
B.—The mean division line between so-called cavity and ordinary stratum.

C. –The ordinary stratum.

Fig. II.



SECTION.

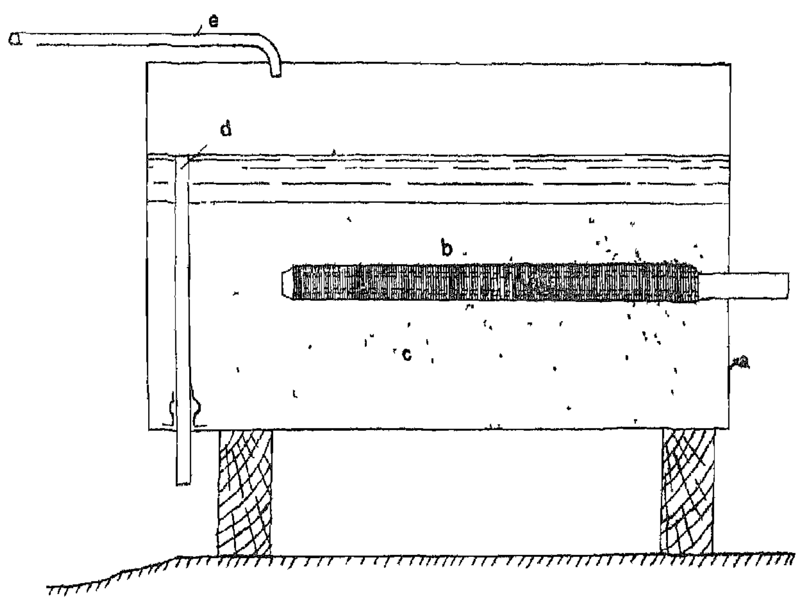


ELEVATION

Photo.-Mechl. and Litho. Dept, Thomason College, Roorkee.

Zinco May, 1913.—No. 9060-1,200.

Fig III

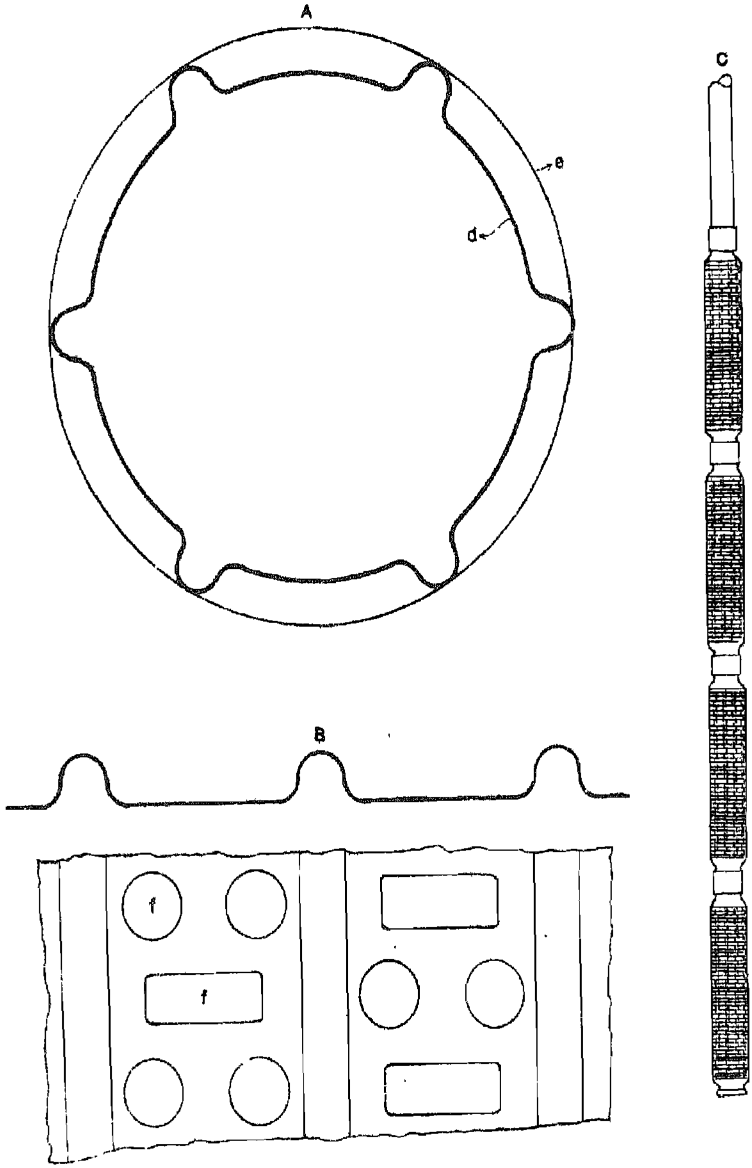


(a), Tank, (b), straining tube, (c), mixture of coarse and fine sand, fine sand being dyed red; (d), over-flow pipe which can be raised or lowered; (e), Inlet pipe

Photo Mechl and Litho Dept, Thomason College, Roorkee.

Zinco, May 1913—No.9060 2-200.

Fig. IV.



A.—Cross section of convoluted tube well; (d), body of tube; (e), straining material.

B.—Piece of convoluted sheet before forming into tube; (f), perforations in sheet.

C.—Elevation of convoluted tube well.

Photo.-Mechl. and Litho. Dept., Thomason College, Roorkee.

Zinco, May, 1912.—No. 9060-3-200.

RECUPERATION CURVE FOR CONVOLUTED TUBE WELL.

DIAMETER OF STRAINER 4½"

WATERWAY AREA OF STRAINER 15 SQUARE FEET.

Note.—The full line shows the recuperation curve plotted from each foot recuperated. The dotted line shows line of theoretical curve calculated from the time constant of the tube.

$$t = \frac{A}{K} = \begin{cases}\text{time constant} \\ \text{time (hours) water rises } 0{\cdot}632\ H.\end{cases}$$

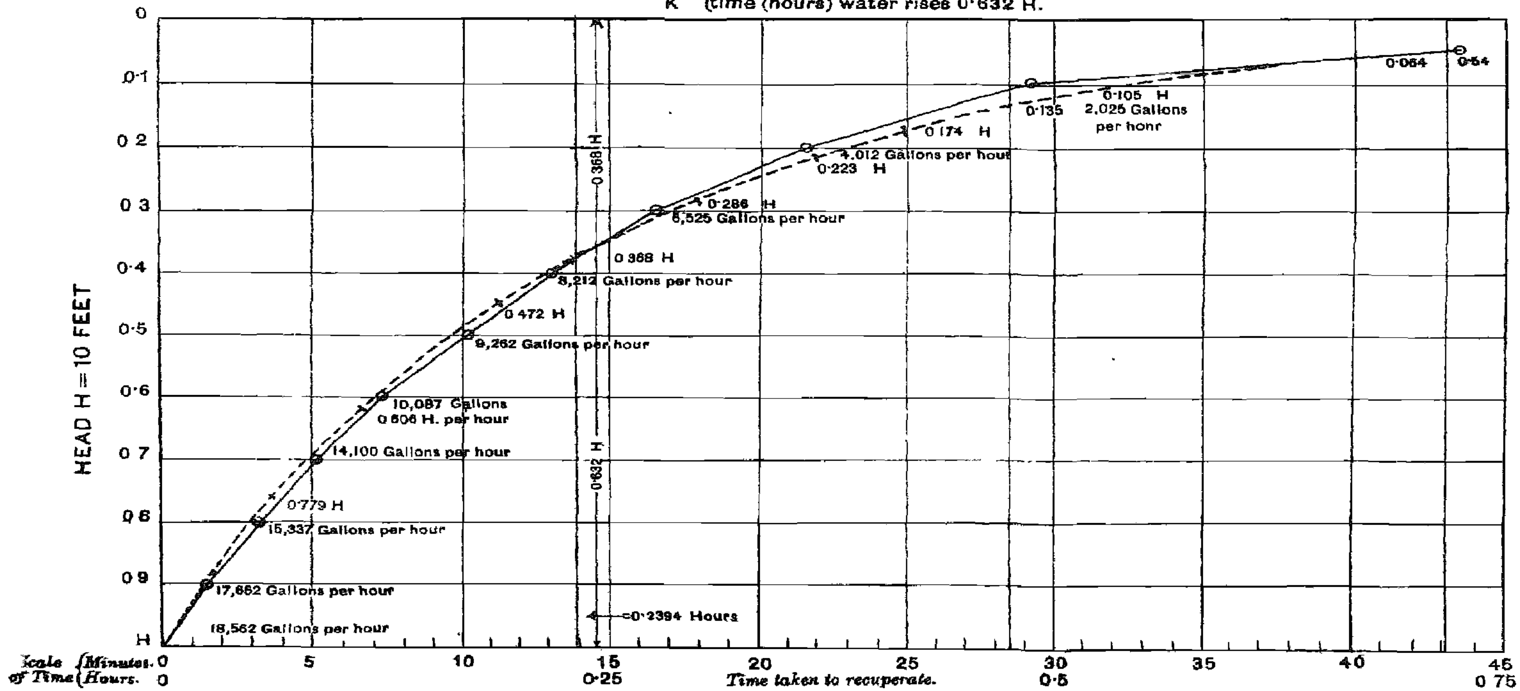


Photo.-Mechl. and Litho. Dept., Thomason College, Roorkee.

Zinco May, 1912.—No. 9060-4.200.